Journal of Elementary Science Education, Vol. 21, No. 1 (Winter 2009), pp. 51-66.

Enhancing Prospective Teachers' Science Teaching Efficacy Beliefs Through Scaffolded, Student-Directed Inquiry

Ling L. Liang, LaSalle University
Greer M. Richardson, LaSalle University

Abstract

This study examined the impact of a recently revised science course that engaged preservice teachers in a scaffolded, student-directed inquiry unit on local streams. Upon the completion of the inquiry project, the teacher candidates in the stream study classes demonstrated significantly greater improvement in the personal science teaching efficacy (PSTE) beliefs than their peers did in the non-stream study classes. Furthermore, the paper reported how the prospective elementary teachers perceived their understandings of science and the instructional strategies related to the stream study unit. Implications and recommendations for future studies are also discussed.

According to the most recent science education reform documents, improving students' understanding of science and scientific inquiry is critical for developing a scientifically literate society (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000). Learning and teaching science as inquiry requires not only grasping scientific information, but also developing fundamental understandings and abilities to conduct scientific inquiry (NRC, 1996, 2000). In this article, we will investigate the effects of a recently revised science course that engaged the prospective teachers in a scaffolded, student-directed inquiry unit on local streams by examining whether the teacher candidates' personal science teaching efficacy (PSTE) beliefs were changed and how the prospective teachers perceived their understandings of science and the instructional strategies associated with the stream study unit.

Background for the Study

Learning and Teaching Science as Inquiry

Scientific inquiry generally refers to the diverse ways in which scientists study the natural world. The publication *Inquiry and the National Science Education Standards* (NRC, 2000) identified the following five essential features of classroom inquiry: (1) learners are engaged by scientifically oriented questions; (2) learners give priority to evidence in responding to questions; (3) learners formulate explanations from evidence to address scientifically oriented questions; (4) learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and (5) learners communicate and justify their proposed explanations.

To further distinguish among various forms of classroom inquiry, science education researchers have also developed an inquiry continuum that classifies classroom inquiry into different levels from structured inquiry to open inquiry. Whereas the traditional confirmatory laboratory experiences, or cookbook labs, usually provide students with step-by-step procedures to verify known principles, in *structured inquiry*, the teacher presents a question, lab equipment, and procedures for students to complete the inquiry. Subsequently, students need to make conclusions based on their findings or results. At the second level of the inquiry continuum, known as *guided inquiry*, the teacher provides a question and lab equipment, while the students design the procedure, analyze data, and make conclusions. In *student-directed inquiry*, the third level, the teacher presents a topic and lets students develop their own questions and design their own investigations. The highest level of the inquiry continuum is referred to as *open inquiry* or *student research inquiry*. At this level, students select topics and investigate their own questions (e.g., Bonnstetter, 1998).

To date, various studies have reported the positive effects that inquiry-oriented science learning and teaching have on preservice teachers' understanding of the nature of science, attitudes and beliefs about science learning and teaching, and their classroom teaching performance (e.g., Adamson et al., 2003; Haefner & Zembal-Saul, 2004; Haim, 2003; McGinnis, Kramer, Shama, Graeber, Parker, & Watanabe, 2002; Richardson & Liang, 2008; Slater, Safko, & Carpenter, 1999). However, the difficulties and limitations of inquiry teaching have also been reported (e.g., Dreyfus, Jungwirth, & Eliovitch, 1990; Riggs & Kimbrough, 2002). Studies suggest that successful inquiry teaching requires significant intellectual commitment on the part of the learners as well as deep cognitive engagement in the subject. Because of this, simply having learners conduct inquiry activities and/or scientific experiments is not sufficient in developing a fundamental understanding of science and scientific inquiry.

The more recent research on learning and teaching has pointed to the importance of *scaffolded inquiry* (i.e., providing scaffolds or written instructional supports during student inquiry) and promoting learners' *meta-cognitive awareness* (i.e., deliberate, conscious control of cognitive activity) in developing lifelong learners (Krajcik, Blumenfeld, Marx, & Soloway, 2000; NRC, 1999, 2005). It has been reported that students who enrolled in inquiry-based science classes with metacognitive facilitation or a reflective assessment component outperformed their counterparts in similar classes without metacognitive facilitation. Furthermore, adding this metacognitive or reflective assessment process to science curriculum was particularly beneficial for conventional lower-achieving learners (e.g., Liang & Gabel, 2005; White & Frederiksen, 2000).

Prospective Elementary Teachers' Beliefs About Learning and Teaching Science

The connection between beliefs, learning, and teaching performance can be captured by the psychological construct of self-efficacy (Bandura, 1977). According to an exhaustive review of the literature on self-efficacy, the evidence across studies has consistently shown that an individual's *perceived self-efficacy* contributes significantly to the level of his or her motivation and performance accomplishments (Bandura, 1977, 1997). In his theory of social learning, Bandura (1977) outlined two components of self-efficacy: (1) personal efficacy and (2) outcome expectancy. *Personal efficacy* refers to the conviction that an individual

can successfully execute the behavior required to produce the desired outcome. An *outcome expectancy* is defined as an individual's estimate that a given behavior will lead to certain outcomes. An individual's personal efficacy beliefs can be fostered through personal mastery experiences, vicarious experiences of models, social persuasion from others, and stress reduction (Bandura, 1994).

Previous research has revealed a relationship among the teachers' personal teaching efficacy, teaching outcome expectancy, and teaching performance. It was suggested that teachers with high self-efficacy showed a greater commitment to student achievement, had higher expectations for their students, and elicited greater student achievement (Ashton & Webb, 1986; Gibson & Dembo, 1984).

Enochs and Riggs (1990) applied the concept of teaching efficacy to science teacher education and developed a valid and reliable instrument entitled the Science Teaching Efficacy Belief Instrument, Form B (STEBI-B). In the instrument, the *PSTE* was defined as an individual's belief about his or her own ability to teach science, while the *science teaching outcome expectancy* (*STOE*) refers to an individual's expectation that student learning can be influenced by effective science teaching. Due to the fact that many preservice elementary teachers had unsuccessful science learning experiences in school and therefore developed negative attitudes and low levels of confidence in learning and teaching science (Liang & Gabel, 2005; Young & Kellogg, 1993), there is a special need to foster the elementary teacher candidates' science teaching efficacy in the nation's teacher education programs.

Since 1990, various studies have employed the STEBI-B to examine the effects of different interventions in enhancing the preservice elementary teachers' science teaching efficacy (e.g., Mulholland, Dorman, & Odgers, 2004; Palmer, 2006; Shroyer, 1997; Tosun, 2000; Young & Kellogg, 1993). Enochs and his colleagues found that the preservice teachers' sense of PSTE was positively correlated with their choice of activity-based science instructional approaches and their perceived effectiveness in teaching science. They also found that the number of college science courses taken and the number of years of high school science taken were negatively correlated with the participants' PSTE, which indicates the inadequacy of traditional science instruction (Enochs, Scharmann, & Riggs, 1995). However, more recent research has shown that teachers who engaged in inquiry-based learning have an increased efficacy or belief in their ability to teach science and mathematics (Haim, 2003; Palmer, 2006; Richardson & Liang, 2008).

Windschitl (2003) followed a group of preservice science teachers from their methods courses through their student teaching experiences. It was found that those who had more authentic views of inquiry and reflected more deeply about their projects in the methods course were not the ones who subsequently practiced inquiry in teaching. Rather, it was those who had extensive previous authentic science research experience who used either guided inquiry or open inquiry in their teaching. Finally, Windschitl advocated that independent science investigations be part of preservice education and that these experiences should be scaffolded to prompt reflection on the nature of inquiry and inquiry-based learning and teaching.

Infusing Environmental Education Content into Teacher Preparation Programs

In the State of Pennsylvania, Environment and Ecology (EE) academic standards (K-12) were established and officially adopted by the Pennsylvania Department of Education in 2002. According to the EE standards, all public

schools are now required to include the following contents in the science curricula: Watersheds and Wetlands; Renewable and Nonrenewable Resources; Environmental Health; Agriculture and Society; Integrated Pest Management; Ecosystems and Their Interactions; Threatened, Endangered, and Extinct Species; Humans and Environment; and Environmental Laws and Regulations. However, few Pennsylvania higher education institutions currently incorporate EE content and pedagogy in their teacher education programs. In a survey conducted by Mastrilli, Johnson, and McDonald (2001), it was reported that only 10% of the responding colleges and universities require a specific course in EE as part of their program. The most notable obstacles to the inclusion of EE content and pedagogy in preservice teacher education programs are the demands upon course time and faculty. One suggestion was that environmental education standards be integrated into existing coursework in a manner which does not significantly increase time demands and workloads or sacrifice the quality of the EE instruction.

This study focuses on two aspects of our efforts to systematically infuse environmental education content into our teacher preparation programs. Specifically, the article examines whether the prospective elementary teachers' science teaching efficacy beliefs were changed as a result of a recently revised science course that engaged preservice teachers in a scaffolded, student-directed inquiry unit on local streams and how the prospective elementary teachers perceive their understandings of science and the instructional strategies related to the stream study unit. The two research questions addressed are as follows:

1. To what extent does the implementation of the stream study unit influence the prospective teachers' science teaching efficacy beliefs?
2. How do the prospective teachers perceive their understandings of science and the instructional strategies associated with the stream study unit?

Methods

In this study, a quasi-experimental design with a qualitative component was adopted to determine whether the implementation of the stream study unit influences the prospective teachers' science teaching efficacy beliefs and how these teacher candidates perceive their understandings of science and the instructional strategies associated with the stream study. The quantitative data were collected in both the stream study and non-stream study classes by using the STEBI-B (Enochs & Riggs, 1990). In addition, the teacher candidates' responses to five metacognitive questions embedded in the unit summaries on the stream study project were gathered and analyzed. This qualitative component would assist with the interpretation of the quantitative data analysis results and provide insights into further improvement of the design and the implementation of the inquiry study unit on local streams.

Sample

The study involved two instructors and 54 prospective elementary teachers who enrolled in four sections of an interdisciplinary science course at a small private university in the Mid-Atlantic area. The majority of participants (more than 90%) were sophomore, female, Caucasian students who had completed one science content course prior to the study.

Curriculum: Investigations in Mathematics and Science (IMS 161)

Existing Curriculum

IMS 161 is the second part of the yearlong science courses sequence required for the elementary and special education (ESE) majors. It was intended to provide opportunities for the preservice teachers to develop conceptual understanding, scientific inquiry skills, and confidence to teach elementary science. Throughout the course, students engaged in small collaborative inquiry groups and investigated such topics as physical and chemical properties of matter, floating and sinking, and behaviors of living things. Instructors facilitated both structured and guided inquiries through classroom-based experimentation, confronting students' alternative conceptions, questioning, discussions, and class presentations. Learners were given opportunities to ask scientifically oriented questions, develop models and formulate explanations using evidence, evaluate their explanations in light of alternative explanations, use mathematics and technology to solve problems, and communicate and justify their proposed explanations. At the conclusion of each unit, each student was required to write a unit summary, illustrating their understandings and reflecting upon what they had learned. The students were encouraged to apply their knowledge to a new problem or to explain everyday phenomena in relation to the concepts in the unit.

In addition to the unit summaries, other traditional and nontraditional assessment tools were used throughout the course such as essays on science-related events in students' everyday lives, concept tests, inquiry projects, and class presentations. More information about the existing curriculum can be found in a previous article by the same authors (Richardson & Liang, 2008).

The Stream Study Inquiry Project

Between spring 2004 and spring 2005, two sections of the IMS 161 course implemented a seven-week-long stream study unit during the second half of the semester, while others continued using the existing IMS curriculum with a classroom-based, structured, and guided inquiry approach throughout the course. Informed by the science education research literature, the instructors implemented a modified version of the student-directed inquiry model in the stream study unit. Given the topic of local streams, the preservice teachers were encouraged to develop their own questions and design their own investigations. In addition, teacher scaffolding and metacognitive facilitation were provided throughout the inquiry project. The criteria and timeline of the student-directed inquiry project are presented in Figure 1. (See Figure 2 for a sample of the scaffolding questions.)

Figure 1. Stream Study Project: Criteria and Timeline

Objectives:

Students will be able to

- plan, design, and implement an inquiry research project on stream study by using resources available (refer to WebCT).
- measure physical-chemical properties of water by using appropriate instruments and apparatus available.
- collect and describe the similarities and differences that characterize benthic macroinvertebrates.
- analyze benthic macroinvertebrates as indicators of water quality.
- present (both orally and in writing) and defend research results before peers/instructors.
- evaluate peers' research results critically and professionally.

Assessment:

Research Agenda	20%	Paper (group)	30%
Presentation (group)	20%	Unit Summary (individual)	30%

Timeline:

Week of the Semester	***Activities***
8	Identify and refine research question(s) via face-to-face and online discussion
9	Literature review, refine research questions, and design investigation via face-to-face and online discussion
11	Field work via face-to-face and online discussion
12	Draft paper due • **Title:** Is the title appropriate in tone and structure to science journals? • **Abstract:** Does it clearly state the purpose of the research and summarize the main findings in 200 to 300 words? • **Introduction:** Does the introduction clearly identify the purpose of the research, include a literature review to provide background information, identify interested audience, and adopt an appropriate tone? • **Methods:** Is the research design consistent with the purpose or research question(s)? Does the section contain effective, quantifiable, and concisely organized information that allows the experiment/observation to be replicated? • **Results:** Are data properly analyzed and presented in tables and/or graphs with self-contained headings? • **Conclusion and Implication:** Are the conclusions drawn consistent with the data and scientific reasoning (avoiding overgeneralizing)? Are explanations of the expected results and suggestions for further research for unexpected results provided? • **Scientific Format and Reference Section:** Are all materials correctly presented and logically organized within each section? Is the reference section presented in a consistent/appropriate format suggested by an instructor? Are a wide variety of sources (at least five) cited?
13	Presentation (organization, eye contact, delivery, and visuals)
14	Final paper due

Figure 2. Sample Scaffolding Questions Posted on WebCT

Asking Questions:

- What do you know about streams? How do streams relate to our daily life?
- What do scientists or experts say about streams? How does the quality of streams affect our daily life?
- What questions or problems do you want to investigate?

Gathering Information:

- How would you identify relevant resources (bibliography) available for answering your questions? What is your list of resources?

Designing and Planning Investigations:

- How would you design an investigation to answer your question(s)?
- What data would you collect?
- How would you collect your data? How would you make sure that your investigation can be replicated by others? How would you know that your measures are reliable (repeatable)?
- Is your plan realistic in terms of the availability of allocated time and resources?

Carrying Out Investigations:

- How would you make certain that you and your team members follow the plan of your investigation to ensure consistency and accuracy in measurements?

Analyzing and Interpreting Data:

- How would you analyze your data?
- What patterns do you see based on your data analysis?
- How would you interpret your data based on your own investigation and what you read during the "Gathering Information" phase? Any alternative interpretations?
- What general conclusions can you make about your investigation?
- What is the value for doing this investigation?
- What new questions are generated from your research project?

At the beginning of the stream study unit, each preservice teacher was assigned to a research team of four or five members with mixed levels of prior scientific understanding based on the course grade prior to the intervention. Information and selected resources related to the stream study project were provided to all participants using a Web-based course management tool called WebCT. Throughout the inquiry project, all team members were required to interact with one another in both face-to-face meetings and through the use of the WebCT group discussion tool. The instructor provided online feedback to students' work-in-progress and supplied scaffolding questions during different phases of the inquiry project (see Figure 2 for sample scaffolding questions). The following is an example of the exchanges between the student research team members and the instructor (pseudonyms are used):

Message no. 105 [Branch from no. 96]
Posted by Kim (XXX) on Thursday, March 18, 2004, at 4:57 PM
Subject: Hi Everyone

Hey Everyone, I was thinking we could do a streamside biosurvey to research the different macroinvertebrates that live in our stream. I'm going to e-mail our instructor with this idea. We can always change it, but this way we at least have an idea sent to her because I think a research question was due by today. Talk to everyone soon! Bye, Kim

Message no. 110 [Branch from no. 105]
Posted by Instructor (XXX) on Thursday, March 18, 2004, at 10:48 PM
Subject: Re: Research topic

Your topic sounds good! Now your group members need to read some background information about macroinvertebrates (identification key can be found on your WebCT resource list). What questions will your group be investigating? What do you mean by "our stream"—are you referring to the one we visited on Wed.? Keep up your good discussion! Take care and see you in class. Instructor

At the end of the project, each student described and explained what scientific knowledge he or she had learned throughout the project in the unit summary. To identify the strengths and the weaknesses associated with the design and the implementation of the stream study project and to help with interpretation of the quantitative data analysis results related to the science teaching efficacy beliefs, all students were also required to respond to the following metacognitive questions embedded in the unit summary: "What did you know about the topic before you began this project?"; "To what extent has the project helped enhance your understanding of scientific knowledge (rate your level of scientific understanding on a scale of 1 to 5)?"; "What strategy, procedure, or techniques did you use to assist you in understanding the material?"; "What strategy, procedure, or techniques were ineffective in your attempts to understand the material?"; and "In what situation(s) could you use the new knowledge in the future?" Finally, each group wrote a formal research paper and presented their research findings to the entire class.

Data Collection

Two major sources of data were collected to answer the following two research questions: (1) student responses to the metacognitive questions embedded in the unit summaries on stream study, and (2) student responses to the STEBI-B (Enochs & Riggs, 1990). The STEBI-B, an instrument consisting of 23 five-point Likert scale statements, was administered as pre- and posttests to both stream study and non-stream study classes at the beginning and the end of the spring semesters of 2004 and 2005.

Data Analysis

To determine the impact of the intervention on the teacher candidates' science teaching efficacy beliefs, the Repeated Measures Analyses of Variance (ANOVA)

with between-subjects factors (*SPSS 14.0*) were adopted to analyze the scores as measured by the STEBI-B (Enochs & Riggs, 1990). The reliability coefficients (alpha) for the PSTE and the STOE subscales were 0.87 and 0.74, respectively.

In order to discern how the students perceived their understandings of science and the instructional strategies related to the stream study, two researchers (both authors) independently conducted the content analysis of student responses to the metacognitive prompts in the unit summaries as described earlier (Borg & Gall, 1989). The intercoder reliability for categorizing the first 19 student responses by the two coders was 0.98, which was calculated using the formula: r = no. of agreements/(total no. of agreements plus disagreements). Discrepancies were resolved through follow-up discussions. Then, the first author completed the categorization of the remaining student responses. Finally, the frequency of each category was counted, recorded, and tabulated.

Results

The results of the study are presented later to answer the following two research questions: (1) To what extent does the implementation of the stream study unit influence the prospective teachers' science teaching efficacy beliefs? and (2) How do the prospective teachers perceive their understandings of science and the instructional strategies associated with the stream study unit?

In order to determine the impact of the intervention upon the teacher candidates' science teaching efficacy beliefs, the STEBI-B was administered to both stream and non-stream groups. A Repeated Measures ANOVA with between-subjects factors on the STEBI-B scores was performed to compare the pre- and posttest results within the stream study class as well as between the stream study and non-stream study class sections. Both the time factor and the interaction between the time factor and the treatment factor (time*group) were statistically significant (see Table 1). This indicates that the students' scores on the personal science teaching efficacy subscale improved significantly over the semester when considering the stream and non-stream study classes as a whole. Furthermore, the stream study classes demonstrated significantly greater gains on the personal science teaching efficacy subscale than their counterparts in the comparison group (see Table 2). No statistically significant differences were found within or between classes on the science teaching outcome expectancy subscale, however.

When asked to describe those effective and/or ineffective strategies, procedures, or techniques used in their attempts to understand the material, the students reported the four most effective strategies and procedures: (1) the use of Internet resources and literature (68%), (2) a field trip (61%), (3) presentations by guest speakers (39%), and (4) group work (36%). The learners also reported some less effective or ineffective procedures such as reading scientific articles and literature (31%), performing the chemical tests without understanding science concepts (14%), that some parts of lectures given by guest speakers were far too advanced or boring (7%), and time constraints for group meetings (3%).

Table 1. Repeated Measures ANOVA for the Science Teaching Efficacy Belief Instrument

Source	*df*	*F*	Partial Eta^2
PSTE			
Between Subjects	53		
Group (stream vs. non-stream)	1	0.97	0.02
Error-between	52	(75.27)	
Within Subjects	54		
Time (pre- and post-)	1	13.51**	0.21
Time × Group	1	7.23*	0.12
Error-within	52	(12.17)	
STOE			
Between Subjects	53		
Group (stream vs. non-stream)	1	0.67	0.01
Error-between	52	(21.99)	
Within Subjects	54		
Time (pre- and post-)	1	0.83	0.02
Time × Group	1	0.22	0.00
Error-within	52	(8.27)	

Note: Values enclosed in parentheses represent mean square errors.
*$p = 0.01$, two-tailed; **$p < 0.01$, two-tailed

Table 2. Mean Scores on PSTE and STOE by Group

Group (Class)	*n*	PSTE Pretest		PSTE Posttest		STOE Pretest		STOE Posttest	
		M	SD	M	SD	M	SD	M	SD
Stream	30	46.20	5.75	50.50	5.58	34.67	3.54	35.43	4.22
Non-stream	24	49.67	7.29	50.33	7.98	35.67	3.12	35.92	4.53

Note: Maximum possible PSTE score = 65.00; minimum possible PSTE score = 13.00; PSTE score for neutral or uncertain = 39.00; maximum possible STOE score = 50.00; minimum possible STOE score = 10.00; STOE score for neutral or uncertain = 30.00. To discern how the prospective teachers perceive their understandings of science and the instructional strategies related to the stream study unit, each individual's responses to the metacognitive questions were examined. On a scale of 1.0 (not at all) to 5.0 (thorough), all of the students but two rated their enhanced level of scientific understanding as 4.0 or 5.0. The remaining two students' self-ratings were 3.0, and the class average self-reported ratings of enhanced scientific understandings was 4.6.

Finally, about 43% of the prospective teachers stated that the stream study unit improved their own knowledge and/or helped them apply what they learned to everyday life. In addition, when asked in what situation(s) they could use the new knowledge in the future, 97% of the prospective teachers made connections between the stream study unit and their future classroom teaching. The participants' responses to each metacognitive question are categorized and summarized in Table 3.

Table 3. Illustrative Examples of Preservice Teachers' Responses to the Metacognitive Questions (n = 30)

Metacognitive Questions	Class Average Score or Categories of Responses	Sample Responses	
1. What did you know about the topic before you began this project?	• There are plants and animals/organisms that live in water (100%) • Streams may be polluted (75%) • Water cycle/precipitation (44%)	Before we began the stream study, I was aware of the fact that streams were a vital part of our ecosystem and that we got our drinking water from them. . . . Through common sense, I knew that there were many organisms that live in streams, and I was aware that pollution could harm these animals. I was unaware of how much streams affect our lives and how much we affect the quality of a stream. (Student #11)	Before being introduced to the stream topic, I was not that familiar with streams. Yes, I know what a stream is and where some local streams can be found, but as far as it being a body of water with rocks, plant life, and organisms, I was clueless. (Student #9)
2. To what extent has the project helped enhance your understanding of scientific knowledge? (Rate your level of scientific understanding on a scale of "1" [not at all] to "5" [thorough].)	Average Score = 4.6	I rate this study a five because it has enhanced my understanding of streams tremendously. As previously stated, my knowledge about streams was little. However, with the help of the instructor and guest speakers, they have exceeded my expectation and I can say that I am firmly comfortable to teach about streams in the future. (Student #3)	I rate "4." Before we began our stream study project, I knew nothing about streams other than some streams are polluted and fish swim in them. During the course of this project, I have been given the chance to acquire a better understanding of scientific knowledge. (Student #5)
3. What strategy, procedure, or technique did you use to assist you in understanding the material?	• Use of Internet resources and literature (68%) • Field trip (61%) • Presentations by guest speakers (39%) • Group work (36%)	To assist me in the understanding of the material, I used online sources that had good pictures and models to help me further understand some things I was unclear on. (Student #8)	I actually think that everything we did in this class was very helpful. We did groups, we had guest speakers, and we went on a field trip. It was all pretty effective. (Student #30)

Table 3 (cont.)

Meta-Cognitive Questions	Class Average Score OR Categories of Responses	Sample Responses	
4. What strategy, procedure, or technique were ineffective in your attempts to understand the material?	• Reading scientific articles and literature (31%) • Performing the chemical tests without understanding science concepts (14%) • Some parts of lectures given by guest speakers were far too advanced or boring (7%) • Time constraints for group meetings (3%)	I think the researching part was ineffective for me. I learned some valuable stuff on what I looked up on the Internet, but I think just reading or researching something does not really let the information sink in. I need to experience something or have someone teach it to me. I am not very good at self-learning. I learn more by being taught and [having] hands-on activities to do. When I research things on watersheds and streams, I thought I knew what they were but was still somewhat unsure. When we went on the first trip to the stream and the lady taught us about them and showed us different tests and information, I had a much better understanding of the material. (Student #21)	The only thing that I think did not help me understand the stream study was some of the guest speaker's talk. I felt that some of it was far too advanced for someone who is not in the science field and most of it went over my head. (Student #1)
5. In what situation(s) could you use the new knowledge in the future?	• Classroom teaching (97%) • Improved understanding about stream, watershed, and water quality (23%) • Application in everyday setting (20%)	In the future, I can use this type of project with my students. When lessons pertaining to the environment and pollution issues, specifically water pollution, are taught, I can discuss with my students components that indicate whether a stream is polluted or not. I can organize field trips to a stream or creek so that students can conduct different tests on the water. This may assist in their understanding of the material. It may also be an enjoyable activity. The students can develop their own conclusions to determine if the stream is healthy or polluted and devise ways of keeping streams clean. (Student #13)	. . . It is always important not to mow the lawn directly up to the streamline. The grass should grow naturally along the bank. It is also significant for there to be trees and shrubs along the bank of the stream. My dad had previously wanted to rip out the trees along the stream to make the backyard more appealing. I have since warned him that doing so will make the stream murky and unhealthy because all of the sediment from the ground will run off into the stream. This experiment made me realize that it is necessary to look at the vegetation around a body of water. (Student #4)

Conclusions and Discussions

Implementation of the reform-based, inquiry-centered school science programs require new models of teacher professional development. The literature suggests that beginning teachers should be engaged in scientific inquiry in college science courses (Grandy & Duschl, 2005). The findings of this study indicate that our revised science curriculum with a scaffolded and student-directed inquiry component was effective in improving preservice elementary teachers' PSTE beliefs. Aligned with the four main factors influencing an individual's personal efficacy beliefs as outlined by Bandura (1994), the following elements may have contributed to the prospective teachers' enhanced PSTE beliefs during the course of study: (1) mastery experiences, noted as the perceived high level of personal success; (2) vicarious experiences, which involved the use of group problem-solving and cooperative learning processes; (3) social persuasion, seen as the perceived cooperative and supportive learning community; and (4) stress reduction, in the form of a sense of meaningfulness, relevance, and enjoyment. Throughout the stream study project, preservice teachers exhibited high levels of interest and commitment to learning as observed by the course instructor.

In our study, we also found a lack of positive change in the science teaching outcome expectancy among the prospective teachers upon their completion of the coursework. This is not surprising because these preservice teachers were sophomore-level students and they may have had few experiences as teachers. Therefore, their expectations may not have been fully realized and open to change. We consider our curriculum revision a success because we have effectively engaged teacher candidates in scientific inquiries relevant to their everyday lives and environment. As a result, we are likely to prepare teachers with both an improved understanding of the process of scientific inquiry and an awareness of environment-related issues, thus providing the prospective teachers with some tools for developing responsible and informed citizenship.

Implications and Recommendations

The findings of this study lend support to the integration of scaffolded, student-directed scientific investigations into the preservice teacher education as suggested by other colleagues in science teacher education (e.g., Windschitl, 2003). By engaging the preservice elementary teachers in scientific inquiry projects related to the real world in science content courses, the teacher candidates would have multiple opportunities to develop their understanding of science and scientific inquiry and, therefore, would be more likely to develop more positive attitudes toward science and become more confident and effective in teaching inquiry-oriented science to their future students.

One limitation of the current study is that we did not have an ideal control group. Whereas both the stream study and the non-stream study classes completed one common unit on "properties of matter" with a similar guided inquiry approach, the other segments of the course contents or topics varied among instructors. Further studies with larger and more diverse samples, as well as improved controls, are needed. It is also recommended that follow-up studies be conducted on students' actual understandings of science content and scientific inquiry as well as actual teaching performances of those preservice teachers with similar inquiry experiences.

Acknowledgments

The preparation of this manuscript was supported in part by grants from the Pennsylvania Department of Environmental Protection (EEF 03-64) and the Lindback Education Foundation. Any opinions, findings, and conclusions or recommendations expressed in this article are those of the authors and do not necessarily reflect the views of the Pennsylvania Department of Environmental Protection nor the Lindback Education Foundation.

References

Adamson, A. L., Banks, D., Burtch, M., Cox, F., Judson, E., Turley, J. B., et al. (2003). Reformed undergraduate instruction and its subsequent impact on secondary school teaching practice and student achievement. *Journal of Research in Science Teaching, 40*(10), 939-957.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy: Project 2061*. New York: Oxford University Press.

Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement*. New York: Longman.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191-215.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.

Bonnstetter, R. J. (1998). Inquiry: Learning from the past with an eye on the future. *Electronic Journal of Science Education*, *3*(1). Retrieved December 9, 2008, from http://unr.edu/homepage/jcannon/ejse/bonnstetter.html.

Borg, W. R., & Gall, M. D. (1989). *Educational research: An introduction* (5th ed.). New York: Longman.

Dreyfus, A., Jungwirth, E., & Eliovitch, R. (1990). Applying the "cognitive conflict" strategy for conceptual change: Some implications, difficulties, and problems. *Science Education, 74*(5), 555-569.

Enochs, L. G., & Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics, 90*, 694-706.

Enochs, L. G., Scharmann, L. C., & Riggs, I. M. (1995). The relationship of pupil control to preservice elementary science teacher self-efficacy and outcome expectancy. *Science Education*, *79*, 63-75.

Gibson, S., & Dembo, M. H. (1984). Teacher efficacy: A construct validation. *Journal of Education Psychology, 76*, 569-582.

Grandy, R. E., & Duschl, R. A. (2005, July). *Reconsidering the character and role of inquiry in school science: Analysis of a conference*. A paper presented at the International History and Philosophy of Science and Science Teaching Group Meeting, Leeds, England.

Haefner, L. A., & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education, 26*, 1653-1674.

Haim, E. (2003). Inquiry-events as tools for changing science teacher efficacy belief of kindergarten and elementary school teachers. *Journal of Science Education and Technology, 12*, 495-501.

Krajcik, J., Blumenfeld, P., Marx, R., & Soloway, E. (2000). Instructional, curricular, and technological supports for inquiry in science classrooms. In J. Minstrell & E. H. Van Zee (Eds.), *Inquiring into inquiry learning and teaching in science* (pp. 283-315). Washington, DC: American Association for the Advancement of Science.

Liang, L. L., & Gabel, D. L. (2005). Effectiveness of a constructivist approach to science instruction for prospective elementary teachers. *International Journal of Science Education, 27*, 1143-1162.

Mastrilli, T., Johnson, P., & McDonald, A. (2001). *Inclusion of environmental education in Pennsylvania teacher preparation curricula: A survey of elementary pre-service teacher programs.* Slippery Rock: Pennsylvania Center for Environmental Education (PCEE). Retrieved October 5, 2003, from www.pcee.org.

McGinnis, J. R., Kramer, S., Shama, G., Graeber, A. O., Parker, C. A., & Watanabe, T. (2002). Undergraduates' attitudes and beliefs about subject matter and pedagogy measured periodically in a reform-based mathematics and science teacher preparation program. *Journal of Research in Science Teaching, 39*, 713-737.

Mulholland, J., Dorman, J. P., & Odgers, B. M. (2004). Assessment of science teaching efficacy of preservice teachers in an Australian University. *Journal of Science Teacher Education, 15*, 313-331.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academies Press.

NRC. (1999). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academies Press.

NRC. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academies Press.

NRC. (2005). *How students learn: History, mathematics, and science in the classroom (Committee on how people learn: A targeted report for teachers)*. M. S. Donovan & J. D. Bransford (Eds.). Washington, DC: National Academies Press, Division of Behavioral and Social Sciences and Education.

Palmer, D. (2006). Durability of changes in self-efficacy of preservice primary teachers. *International Journal of Science Education, 28*, 655-671.

Pennsylvania Department of Education. (2002). *Academic standards for environment and ecology.* Retrieved January 26, 2009, from www.pde.state.pa.us/stateboard_ed/cwp/view.asp?Q=76716.

Richardson, G. M., & Liang, L. L. (2008). The use of inquiry in the development of preservice teacher efficacy in mathematics and science. *Journal of Elementary Science Education*, *20*(1), 1-16.

Riggs, E. M., & Kimbrough, D. L. (2002). Implementation of constructivist pedagogy in a geoscience course designed for pre-service K-6 teachers: Progress, pitfalls, and lessons learned. *Journal of Geoscience Education*, *50*, 49-55.

Shroyer, M. G. (1997, January). *Enhancing preservice elementary teachers' science teaching self-efficacy beliefs: A longitudinal inquiry*. A paper presented at the Annual Meeting of the Association for the Education of Teachers in Science, Cincinnati, OH.

Slater, T. F., Safko, J. L., & Carpenter, J. R. (1999). Long-term attitude sustainability from a constructivist-based astronomy-for-teachers course. *Journal of Geoscience Education*, *47*, 366-368.

Tosun, T. (2000). The beliefs of preservice elementary teachers towards science and science teaching. *School Science and Mathematics*, *100*, 374-379.

White, B. Y., & Frederiksen, J. R. (2000). Metacognitive facilitation: An approach to making scientific inquiry accessible to all. In J. Minstrell & E. H. van Zee (Eds.),

Inquiring into inquiry learning and teaching in science (pp. 331-370). Washington, DC: American Association for the Advancement of Science.
Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education*, *87*, 112-143.
Young, B. J., & Kellogg, T. (1993). Science attitudes and preparation of preservice elementary teachers. *Science Education*, *77*(3), 279-291.

Correspondence regarding this article should be directed to

Ling L. Liang
Department of Education
LaSalle University
1900 W. Olney Avenue, Olney Hall-268
Philadelphia, PA 19141
(215) 951-1174
Fax: (215) 951-5029
liang@lasalle.edu

Manuscript accepted March 6, 2008.